THE AUTOMATED GROUND NETWORK SYSTEM

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Summary

The primary goal of the Automated Ground Network System (AGNS) project is to reduce Ground Network (GN) station life-cycle costs. To accomplish this goal, the AGNS project will employ an object-oriented approach to develop a new infrastructure that will permit continuous application of new technologies and methodologies to the Ground Network's class of problems. The AGNS project is a Total Quality (TQ) project. Through use of an open collaborative development environment, developers and users will have equal input into the end-to-end design and development process. This will permit direct user input and feedback, and will enable rapid prototyping for requirements clarification. This paper describes the AGNS objectives, operations concept and proposed design.

1 Introduction

The National Aeronautics and Space Administration (NASA) Ground Network has gradually evolved over the years to satisfy changing requirements and to accommodate new technologies. It has effectively satisfied mission requirements and has generated an enviable record of station availability and performance. However, the evolutionary process has resulted in a diverse collection of aging, custom equipment that is becoming increasingly more difficult and expensive to maintain. Technology advances over the past few decades allow for "better, faster, and cheaper" ground tracking stations. The goal of the Automated Ground Network System (AGNS) project is to use these advances to implement dramatic improvements in station life-cycle operating costs and efficiencies. Since technology will continue to advance, and requirements will continue to change, the project must provide for continuous technology insertion with minimal disruption to routine operations.

Every automation project is unique because every system has unique requirements and constraints. Although other automated tracking systems exist, such as the United States Air Force's Automated Remote Tracking Station (ARTS) and the Wallops Transportable Orbital Tracking System (TOTS),

these systems are not designed to accommodate the Ground Network's unique requirements. The Ground Network tracking stations at Merritt Island and Bermuda are unique because they support launch and landing of manned spacecraft, as well as provide orbital support for a very wide variety of spacecraft. By contrast, the ARTS was designed to provide repetitive orbital support for many different spacecraft with similar or identical receive and command formats. The TOTS was designed to provide repetitive orbital support for a few spacecraft, and it was optimized for portability and simplicity.

During the history of the Ground Network, there have been numerous attempts to automate portions of the stations and their operations work-loads. Station requirements have always been fluid, and the technology did not always exist to cost-effectively automate work to the extent desired. The AGNS project has paid close attention to the lessons of history. The most important of these is that the stations must have significant input in the early stages of the project. Much of the work at each site is repetitive, but there are day-to-day variations. A design that is inflexible, or inappropriate, will not achieve the desired efficiencies and may not work at all. Significant and continuous operator input is in keeping with the project's TQ approach, and permits NASA to draw upon hundreds of person-years of experience available at the sites. This commitment to learning from the users and implementing tools to ensure their input is critical to project success.

This paper describes the AGNS project's objectives, its scope, and its approach to reducing life cycle costs. Section 2 describes work at the current Ground Network stations that is amenable to automation, and it outlines AGNS project objectives as they relate to this work. Section 3 describes the scope of the AGNS project and the major subsystems the project will implement. Sections 4 through 6 describe the AGNS Development Facility, Maintenance and Support Network and the Monitor and Control Subsystem.

2   Project Objectives

The AGNS project, managed by the Telecommunication Systems Branch (Code 531) at GSFC, will enable more cost effective GN tracking station support. The objectives of the AGNS project are to:

a.   Significantly reduce station life-cycle costs.

b.   Improve station reliability, maintainability, and availability.

c.   Enable and enforce the use of internationally-recognized communications standards and protocols.

d.   Provide a flexible station architecture that can readily accommodate future requirements

and technology with minimum effort and cost.

Operations and maintenance costs for the GN tracking stations at Merritt Island and Bermuda and the wing site at Ponce De Leon are driven by many factors. These include a tightly coupled and complex software architecture; the use of large numbers of different, custom communications interfaces; and labor costs that are driven by the peak work loads encountered during preparation for, and support of, Shuttle launches and landings.

First, the existing stations' architecture is tightly coupled. Changes in one subsystem often impact equipment and procedures elsewhere on the site. This necessitates extensive regression testing when making software modifications. Such testing often impacts external users as well as station operations.

Second, since existing station equipment uses a variety of custom communications interfaces and protocols rather than interfaces based on internationally-recognized standards and protocols, it is difficult to use commercial off-the-shelf (COTS) equipment for system upgrades. Some degree of tailoring is invariably necessary. This increases development effort, complexity and cost. A further consequence of these low levels of interoperability is that it is very difficult to reallocate processing among subsystems, so they are often replaced on a "one-for-one" basis, perpetuating the problem.

Finally, labor costs are the single largest component of station operating expenses, and since the number of operators is determined by peak, not average work loads, the cost to operate the GN is significant.

The AGNS will simplify station maintenance and reduce operations costs. The project will:

a. Use loosely coupled subsystem building blocks to simplify new development and minimize requirements for regression testing.

b. Encapsulate station functionality in "black boxes" that hide implementation details from other subsystems and provide well defined messaging interfaces for exchange of data.

c. Automate station configuration, testing, fault isolation and recovery.

d. Utilize expert systems to capture operator knowledge, filter display information to avoid operator overload and to respond to contingencies.

e. Enforce the use of common, commercial standards, interfaces and equipment.

f. Provide centralized monitor and distributed control capabilities.

3 Project Scope

The AGNS project addresses only the GN tracking stations at Merritt Island and Bermuda. It is not within the scope of this project to modify configurations, interfaces and operational procedures at other GN sites or other locations such as Johnson Space Center (JSC), Goddard Space Flight Center (GSFC), Kennedy Space Center (KSC), Department of Defense (DoD) sites or in the NASA Communications (Nascom) network. The AGNS project provides capability for external operators (at the Network Control Center for example) to access information and control activities, if required.

The AGNS project presently consists of three subprojects: the AGNS Development Facility (ADF), the AGNS Maintenance and Support Network (MSN), and the AGNS Monitor and Control Subsystem (MCS). The ADF will provide developers and the sites with the tools necessary to prototype, develop, test, and maintain other subprojects in support of the system. The MSN will permit station personnel to share these tools, enabling their early and continuous participation in system requirements analysis and design. The MSN will also enable sustaining engineering personnel at contractor facilities to remotely troubleshoot and monitor station subsystems. The MCS will provide interactive, real-time monitor and control of stations' equipment.

4 AGNS Development Facility

The ADF is a distributed facility with components at GSFC, Merritt Island, Ponce De Leon and Bermuda. The ADF at GSFC will be a remote extension of the stations' monitor and control subsystems. Developers will work interactively with site operators and engineers to prototype, evaluate, test, iterate and refine:

  a.   System displays and control procedures.

  b.   Expert system rule bases for operations resource scheduling and fault management.

The ADF equipment is all COTS and will be database-driven. Resource editors and commercial databases will define and store the parameters that define system appearance and behavior. This will permit rapid changes, but will require only minimal regression testing. This concept has already been successfully demonstrated in development and implementation of the Gamma Ray Observatory Remote Terminal Subsystem in Canberra, Australia. Development cycle times were reduced from weeks to only hours through the use of database-driven subsystems, electronic interaction with site equipment from GSFC and electronic exchange of system development and project management information.

5   AGNS Maintenance and Support Network

The AGNS Maintenance and Support Network (MSN), as shown in Figure 1, will consist of a number of workstations and Ethernet local area networks (LANs) interfaced to the National Science Foundation Internet via a Program Support Communications Network (PSCN) Gateway.
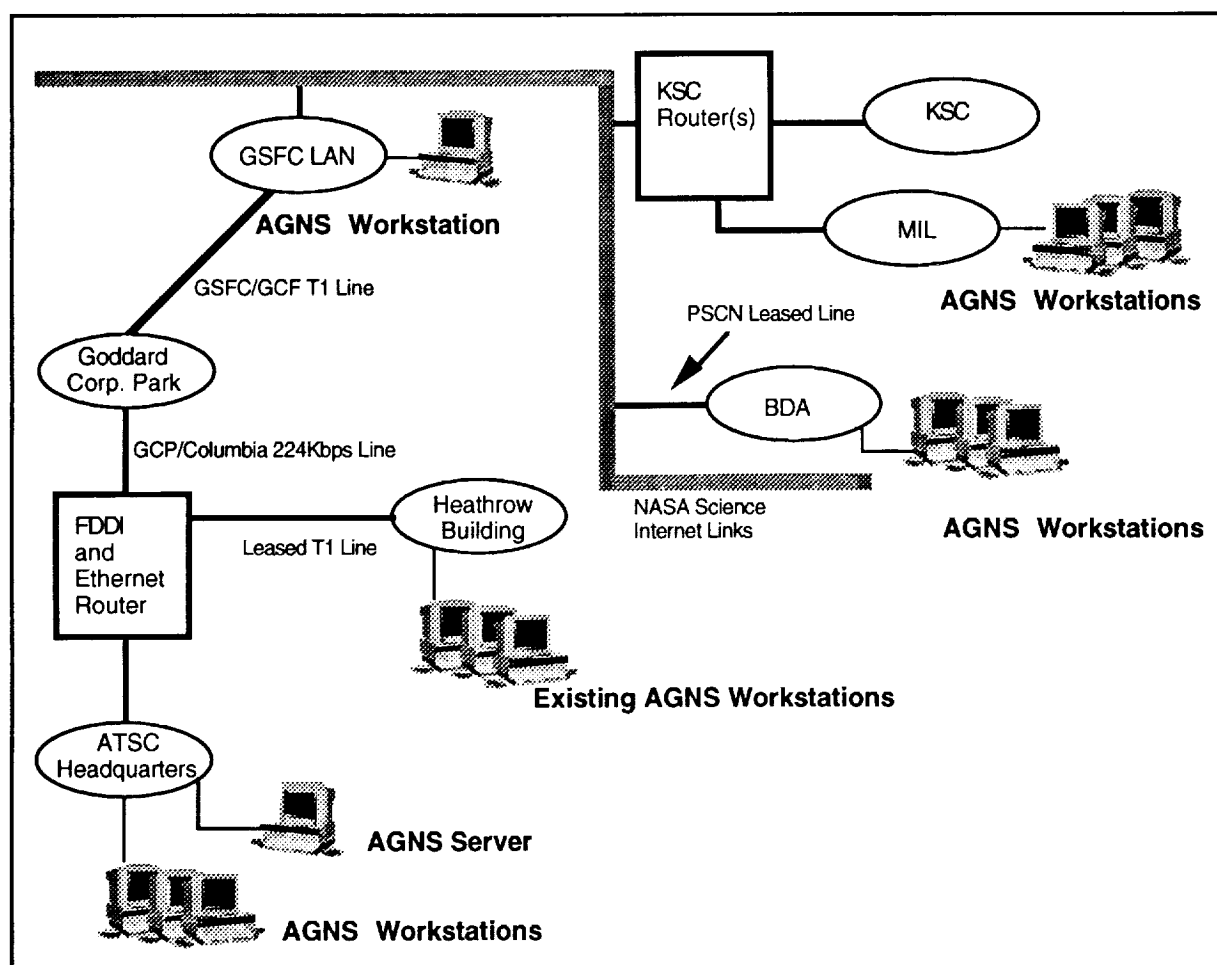

Figure 1 AGNS Maintenance and Support Network

The MSN will reduce life cycle costs by:

a. Providing effective electronic connectivity for electronic mail services and electronic conferencing, thereby improving communications between the sites and GSFC.

b. Providing seamless integration with major Networks Division (Code 530) Management Information Systems including the Technical Information Program (TIP), the Engineering Change Automation System (ECAS), the Facilities Automation System (FAS), and the

Enhanced Logistics Information Management System (ELIMS).

c. Reducing development cycle times

d. Enabling remote troubleshooting and reducing response times when problems occur.

e. Improving system performance analysis.

f. Sharing project management information between GSFC, contractors and the sites.

For security reasons, the AGNS Maintenance and Support Network will not be connected to the AGNS Monitor and Control Subsystem network until a trusted interface is identified or developed.

6 AGNS Monitor and Control Subsystem

The AGNS MCS approach is based on careful review of current station operations. During project planning activities, site personnel and developers attempted to define the capabilities of successful operations teams and important features of their approach to identify key attributes of a good MCS design.

The lessons of two decades of station operations are clear. To significantly reduce operations staffing, any MCS must provide complete equipment control. Feedback must be comprehensive and fast, but must not overload operators with status information. Prioritizing and hardwiring status information works only until an unanticipated problem occurs. All the status information must be available for selection, but only that data desired at any specific instant should be presented to the operator. Similarly, the control functions needed at any moment should be the easiest ones to access.

It is valuable to examine why these lessons have not been applied in the existing GN. The key reasons appear to be:

a. Limited processing resources. Computers built in the 1970's did not have the speed or memory required to sample data and status, make preliminary analyses, draw conclusions and offer suggestions to operators.

b. Primitive development approaches. No development methodologies existed to rapidly, safely, and cheaply iterate monitor and control approaches. The developers' best guesses by Critical Design Review time defined the subsystems and their operating modes for the remaining life of the equipment.

The proposed monitor and control approach for the AGNS is to provide all of the relevant equipment audio and visual cues that exist today to any operator, independent of location. Sites

will specify different kinds of support scenarios and will identify information that is important in those contexts. Since it is impractical to define all possible scenarios during the design phase, all screen displays and control interactions will be defined in operator-accessible databases. Users will define all the interfaces through an iterative, prototyping approach. The equipment and software configuration and behavior will be defined by parameters stored in external databases. By modifying information in the databases, site personnel will be able to modify station processing and displays. This will permit them to make changes locally in minutes or hours. Presently, it can take weeks or even months to modify and test system software. New configuration management procedures have been defined and will be used to manage this shortened development cycle.
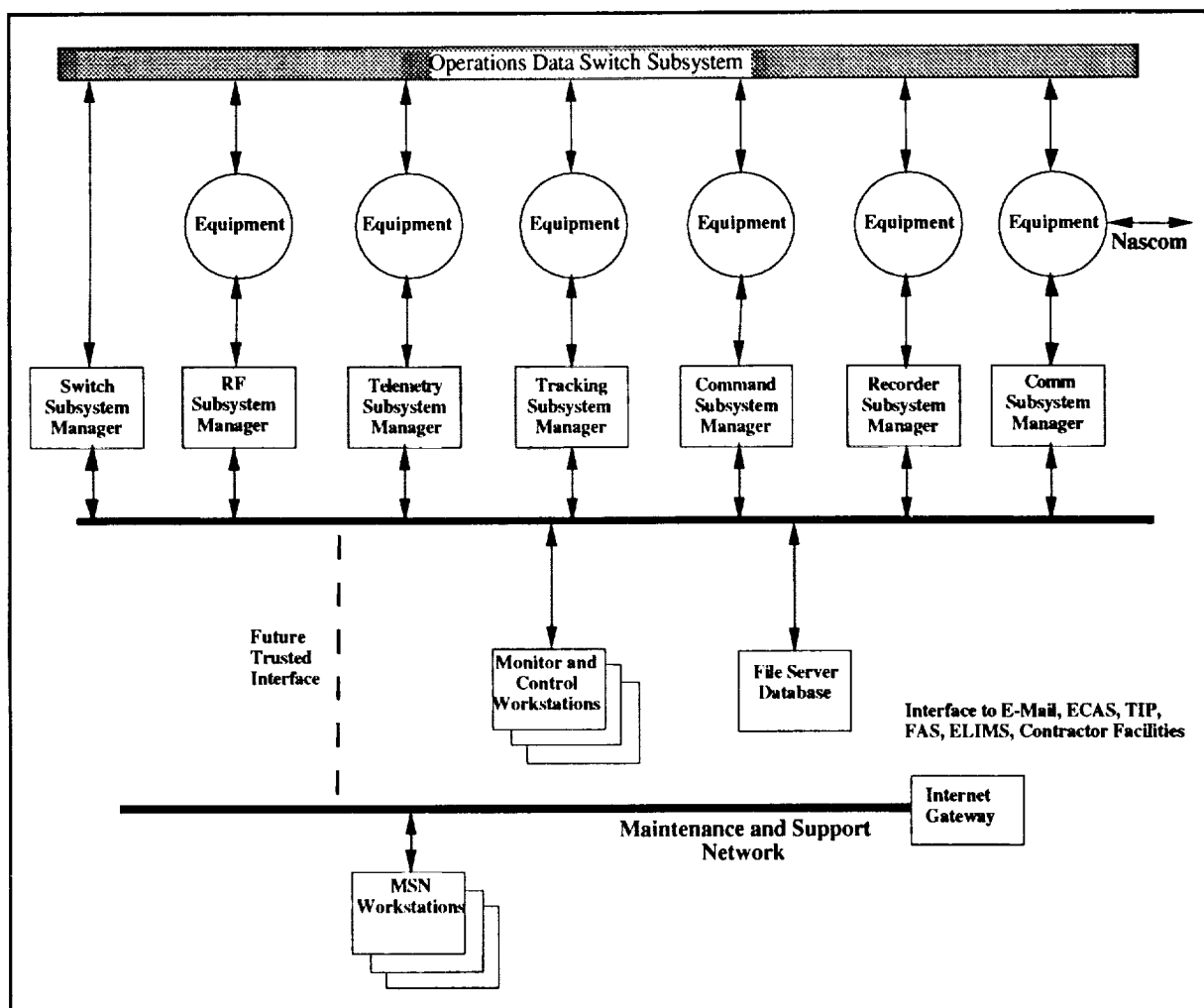

Figure 2   AGNS Station Architecture

As shown in Figure 2, the AGNS MCS will comprise a file server/database, a series of distributed subsystem managers, a small number of centralized monitor and control workstations, and an

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Operations Data Switch Subsystem – all interconnected via a communications network using standard communications protocols. The database will store important subsystem equipment configuration parameters for all supported spacecraft, as well as the station's mission support schedule. The subsystem managers will encapsulate the details of the individual subsystem components, will provide well-defined monitor and control interfaces, and will utilize expert systems to help automate subsystem configuration, testing, fault detection and recovery.

The subsystem managers will monitor and control their subsystem components via real-time databases. The real-time databases will function as a "presentation layer" between operator workstations and equipment. They will provide status information to the centralized monitor and control workstations, which will display the status using a standard graphical operator interface. These workstations will also transmit control information, via the real-time databases, to the subsystem managers.

The system schedule will define overall operations requirements. The subsystems will decide locally how to implement those portions of the schedule that they can accommodate. During equipment configuration and fault recovery operations, subsystem managers will transmit status messages to the Switch Subsystem Manager. This manager will interconnect the subsystem processing strings as required, using the Operations Data Switch Subsystem. A detailed record of all configurations will be maintained for subsequent fault or performance analysis, should this be necessary.

This object-oriented architecture will reduce coupling between subsystems and will create a hierarchical monitor and control design structure. In a typical operations scenario, the schedule, which is a high-level document, will be received at the AGNS station from the Network Control Center (NCC). This schedule will be stored in a site database where it will be accessible to each of the subsystem managers. Each subsystem manager will query the database using a Structured Query Language (SQL) protocol to obtain relevant portions of the schedule. Each manager will know, from its local knowledge base, the necessary frequencies, bit rates, and other configuration parameters required for its subsystem to satisfy its specified support functions or requirements. The managers will then allocate resources to each function.

Subsystem managers will be aware of the status and allocation of all components they control, and they will be locally responsible for resource allocation. Status information will be available to external subsystems if desired, but this information will have to be requested from the manager.

At the requested time of support, each subsystem manager will read its schedule requirements from the central database, will allocate and test subsystem components, and will send a status message to the Switch Subsystem Manager informing it of which subsystem components it is contributing

to the overall processing string. The Switch Subsystem Manager will use this information to control the actual data paths in the Operations Data Switch Subsystem.

7 Conclusion

The AGNS project will implement a modular, expandable, flexible station architecture. It will employ expert system technologies to capture operations knowledge and reduce personnel peak work loads. The project will implement a collaborative development environment to shorten development cycles and converge on effective engineering solutions in the shortest possible time. The architecture will permit continuous technology insertion, ensuring that NASA can make maximum use of new, cost-effective technologies as they become commercially available.

Although the AGNS project will provide the Ground Network with a new infrastructure that will enable significant life-cycle cost reductions, these cost reductions will not be fully realized until the old, custom equipment is replaced with new, standard equipment. The Telecommunication Systems Branch plans to replace this equipment over the next few years. A "better, faster, and cheaper" Ground Network should soon be a reality.